Some Comparisons of BTeV's Staged Physics Reach with LHCb

BTeV Collaboration

June 2, 2004

Executive Summary

The HEPAP subpanel P5 recommended construction of BTeV based on its ability to be the best heavy flavor experiment in the period 2009-2014, or longer. They said: "The strength of the BTeV experiment comes from the combination of its vertex trigger with precision mass measurements for both charged and neutral decay modes and excellent particle identification capabilities."

We are now planning to install a staged detector for the first seven months of operation, followed by a short shutdown to install the rest of the detector. This results from the desire to create a schedule with a good fraction of a year of schedule contingency for the major systems consistent with the present funding profile. The staged detector will maintain the full pixel detector andtrigger system that allows triggering on all B decays at a rate about 5 times that of LHCb. The tracking system will be complete except for some downstream layers that are mostly needed for additional redundancy. For charged decay modes, the ones for which LHCb is most competitive, the product of trigger, tracking, and flavor tagging efficiencies for the staged detector will be about 75% that of the full detector.

Only half of the electromagnetic calorimeter will be installed for Stage I. As a result, the efficiencies for neutral decay modes in the first running period for BTeV will be typically about 60% of that with the full detector. Since LHCb does not have a crystal calorimeter at all, the staged BTeV detector will far outperform LHCb for these modes. The other staged elements will principally reduce the trigger rate for charm physics, not for the most important physics goals of BTeV.

To reach a given error on the CP-violating parameter γ from $B_s \to D_s^{\pm} K^{\pm}$ will take half as much integrated luminosity with BTeV Stage I as with LHCb. BTeV will get over twice as much integrated luminosity in the 10-month running year at the Tevatron, however, than LHCb is expecting to get in the 5.3-month running year with protons at the LHC. The measurement of the CP violating parameter α with BTeV stage I using the decay mode $B \to \rho\pi$ will dominate that of LHCb even with the smaller crystal calorimeter. BTeV stage I will be able to write about 5 times as many B mesons to tape without regard to specific decay modes than LHCb, which will be a great advantage in looking for surprises, as the B-factories are able to do now. After the full BTeV is installed its rate for observing CP violating decay modes containing neutral particles will double.

LHCb is likely to get some data before BTeV turns on. However, since there will have been data taken by the e^+e^- B-factories on B^o and $B^{\mp}$ decays and CDF and D0 on B_s decays, the first year or two of LHCb running, that will have a relatively low integrated luminosity, will be used, most likely, to merely catch up to the level of accuracy attained by by these older experiments.

In summary, BTeV Stage I will maintain the advantages over LHCb that led to its strong approval by the Fermilab Physics Advisory Committee and P5. For the charged modes, in which LHCb is most competitive, Stage I will represent a 75% efficiency relative to full BTeV. For the neutral modes, in which BTeV will dominate LHCb, the efficiency of the staged detector will be about 60% when flavor tagging is not required and 45% when it is.

As soon as the BTeV collaboration is able to reconstruct data and do the physics analysis, a challenging process that will take some time for any experiment, it will be leading the world in most important B physics modes and it will be completely dominant in several key areas.

Contents

1.1 Introduction

The BTeV project consists of the Detector, the Interaction Region (IR) and outfitting the C0 hall to be able to support the installation of the detector, the IR and the continued running of the experiment. The detector will be installed in two stages in order to ensure enough flexibility in its schedule to guarantee that it will be installed on schedule. The IR and outfitting are planned to be completed in time for the Stage I detector.

The BTeV detector is described in detail in the BTeV Technical Design Report (TDR) [1]. Briefly, it is a forward spectrometer following the anti-proton direction in the C0 collision hall of the Tevatron collider. It includes a pixel detector, embedded in the machine vacuum, inside of a dipole magnet, whose main function is to measure very precisely the positions of charged tracks and send this information to the trigger which is implemented to detect the presence of decay vertices of b and c quarks. The charged tracks then traverse a series of detection planes consisting of silicon strips close to the beam line and straw tube based wire chambers at larger distances that measure their momenta. There is a Ring Imaging Cherenkov Detector, (RICH) to identify charged particles, an electromagnetic calorimeter that detects photons and electrons and a system to identify muons using a toroidal magnet. The primary trigger is based on detecting detached heavy quark vertices. There is another trigger for dimuon events that is used mainly to evaluate efficiencies. There is also a high capacity data acquisition system.

In order to ensure that we can take physics quality data at the end of 2009, we have developed a "staged" construction and installation plan. The staging will we done in two steps. The installation of the first stage detector will start on Aug. 1, 2009.

We plan to install the following components for the Stage I detector:

- The complete pixel detector;
- The gas radiator RICH system, the liquid radiator with 25% of the readout photomultiplier tubes;
- One half of the $PbWO_4$ crystals in the EM calorimeter;
- Two out of the three planes of Muon detector;
- Five of the Forward Straw Tracker stations, numbers 1, 2, 5, 6, and 7. We will also install the Forward Silicon Microstrip stations 1, 2, 5 and 6.
- The detached vertex trigger and one half of the trigger and DAQ throughput.

The parts of the detector that we do not commit to in the first stage are

- 75% of the photomultiplier tubes used for the Ring Images of Cherenkov photons generated in the liquid radiator;
- 50% of the $PbWO_4$ crystals from the EM calorimeter;

- One Muon tracking station and the dimuon trigger;
- 50% of the trigger and DAQ capabilities;
- The Straw Tracking stations 3 and 4 and the Silicon Microstrip stations 3, 4 and 7.

We are committed to installing these parts of the detector in the second installation stage starting July 1, 2010.

In this note we compare the physics reach of BTeV Stage I and Stage II to that of LHCb as a function of time. The physics case for BTeV can be found on the web at [2].

1.2 General Comparisons with LHCb

LHCb [3] is an experiment planned for the LHC with almost the same physics goals as BTeV. BTeV is at least as good as LHCb in all areas and it is far superior in some very important areas. Both experiments intend to run at a luminosity of 2×10^{32} cm^{-2}s^{-1}. There are several inherent advantages and disadvantages that LHCb has compared with BTeV. The issues that favor LHCb are:

- The b production cross-section is expected to be about five times larger at the LHC than at the Tevatron, while the total cross-section is only 1.6 times as large.
- The number of interactions per bunch crossing is expected to be about 3 times lower at the LHC than at the Tevatron.

The issues that favor BTeV are:

- BTeV is designed to have the vertex detector in the magnetic field, thus allowing the rejection of low momentum tracks at the trigger level. Low momentum tracks are more susceptible to multiple scattering which can cause false detached vertices leading to poor background rejection in the trigger [5].
- BTeV is designed with a high quality $PbWO_4$ electromagnetic calorimeter, far superior to that of LHCb, that provides high resolution and acceptance for interesting final states with γ's, π^o's, and $\eta^{(\prime)}$'s [6].
- The LHCb data acquisition system is designed to output 200 Hz of b decays, while BTeV is designed for larger output bandwidth of 1,000 Hz of b's and 1,000 Hz of charm, and an additional 2000 Hz for contingency, calibration events, and other physics. Therefore, BTeV has access to a much wider range of heavy quark decays.
- The running schedule at the LHC is estimated to be only 160 days per calendar year after initial shakedown. This does not include any Heavy Ion running which would subtract at least 28 days from the total. At LHCb's running luminosity of 2×10^{32}cm^{-2}s^{-1}, the integrated luminosity per calendar year is expected to be 0.8 fb^{-1} [7]. BTeV expects to run 10 calendar months and should integrate 1.6 fb^{-1} in the steady state [8].

- BTeV has to cover a smaller range of particle momenta. The seven times larger beam energy at the LHC makes the momentum range of particles that need to be tracked and identified much larger and therefore more difficult. The larger energy also causes a large increase in track multiplicity per event, which makes pattern recognition and triggering more difficult.

- The interaction region at the Tevatron is six times longer along the beam direction than at LHC ($\sigma_z = 5$ cm), which allows BTeV to be able to accept collisions with a mean of up to six interactions per crossing, since the interactions are well separated in z. LHCb tries to veto crossings with more than one interaction.

- The short bunch spacing at the LHC, 25 ns, has serious negative effects on all their detector subsystems. There are occupancy problems if the sub-detector integration times are long. This can be avoided by having short integration times, but that markedly increases the electronics noise. For example, in a silicon detector these considerations make first level detached vertex triggering more difficult than at the Tevatron [4].

- Use of a detached vertex trigger at Level 1 allows for an extensive charm physics program absent in LHCb. It also accepts a more general collection of b events, which are less oriented towards particular final states.

- LHCb must tolerate far higher beam currents and their associated backgrounds through their detector that support luminosities of $10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ in other interactions regions.

We have compensated for LHCb's initial advantages in b cross-section due their higher center-of-mass energy. In fact, the high energy actually works in many ways as a disadvantage. For example, LHCb needs two RICH counters to cover the momentum range in their one arm. Particle identification and other considerations force LHCb to be longer than BTeV, in fact about twice as long. As a result, LHCb's transverse area is four times that of BTeV, in order to cover the same solid angle. It is expensive to instrument all of this real estate with high quality particle detectors. Thus, the total cost for LHCb based only on instrumented area, (a naive assumption) would be four times the total cost for BTeV.

For our Proposal and Proposal Update, we compared our physics reach with that of LHCb as documented in their Technical Design Report [3] and a B Physics at the LHC document [9]. Recently, however, they have extensively redesigned their detector and now call it "LHCb Light" [11] [12]. The changes were prompted at least partially by them not using the proper Pythia generator (they were using version 5.7 rather than 6.2, while BTeV always used 6.2) and their realization that they had too much material in the upstream part of the detector. The changes include reducing the number of silicon strip detectors in their vertex detector from 25 to 21 and lowering the silicon thickness from 300 to 220 μm, reducing the number of tracking stations, removing the magnet shielding plate, thus allowing field on the vertex detector and RICH-1, and adding a high p_t only trigger which helps primary on $B \to h^+h^-$ final states.

While LHCb has done some studies of their physics sensitivities in this new configuration, they are not as extensive as before and in some cases they computed efficiencies in this new configuration but do not have enough background events do determine their background; furthermore our experience is that you may have to drastically retune your signal selections when you find out about the backgrounds you have to fight, and this could materially lower their efficiencies. We are particularly concerned that in "LHCb Light" their ghost track rate on tracks going through the entire spectrometer is between 3-8%, depending on p_t, while the BTeV ghost rate is less than 1% for similar tracking efficiency of 95%.

1.3 Assumptions About Schedules

Besides the inherent differences in the two experiments, the machine commissioning phases will be quite different. BTeV is operating at an existing machine and the period to make useful luminosity should be quite short, on the order of a month, while LHCb will be born at a brand new accelerator.

Let us first consider the steady state luminosity for LHCb. Collier gives his expectations of the steady state running of the LHC [7] after the first year or two of shake down. The yearly physics running of LHC is limited to 160 days minus that used for heavy ion running that subtracts at least another 21 days. Using Collier's efficiency factors and an initial starting luminosity of 2.8×10^{32}cm^{-2}s^{-1}, LHCb will integrate 0.8 fb^{-1} in the steady state [13].

BTeV is expected to run for 10 months a year, about a factor of two more running time than LHCb. In steady state, BTeV will accumulate 1.6 fb^{-1} per year [8].

The official LHC schedule at the time of this writing is to have some beam starting in April of 2007 with a short runs to the experiments over the next year. The initial bunch spacing will be 75 ns, which causes a problem for LHCb because of multiple interactions per crossing and, in addition, they need special setups to get useful luminosity [14]. Thus, they will collect about 0.1 fb^{-1} in 2007. Starting in April 2008, the running will shift to 25 ns bunch spacing, the luminosity will increase and LHCb could optimistically accumulate three-quarters of year of steady running or 0.6 fb^{-1}. In 2009 they would accumulate 0.8 fb^{-1}.

This schedule however is aggressive and has no "float." To compare with the schedule BTeV is encouraged to make it would be reasonable to add one year of float to the LHC schedule. (Of course, even if they met this schedule they would be a great success.) Here LHCb accumulates 0.1 fb^{-1} in 2008, 0.6 fb^{-1} in 2009 and 0.8 fb^{-1} in 2010 and beyond. Since we do not know which of the these schedules will actually occur we will compare with both of them.

BTeV installs the interaction region magnets and the Stage I detector in 2009 and has a month of running to commission the interaction region. The BTeV schedule mandates 6 months of running with the Stage I detector in 2010, accumulating 1 fb^{-1} followed by a shutdown and then another 3 months of running with the Stage II detector, accumulating 0.5 fb^{-1}.

In the case of both LHCb and BTeV we have not included any time for detector "shake-down," which is assumed to be the same for both experiments and should therefore add a roughly similar amount to both timelines [10].

To give a general idea of one key difference between the two experiments, we show the total number of $b\overline{b}$ events written to "tape" in Fig. 1.1. For purposes of this example we derated the BTeV Stage I detector by an overall factor of two with respect to the Stage II system. We see that by the end of 2010 BTeV will have between a factor of two and a factor of three more accumulated events than LHCb. The large difference in the number of accumulated events is due to two facts: first of all, BTeV is designed to write more than five times as many b-events to "tape," and BTeV runs twice as long each year at the same luminosity. *The large number of events becomes important when new modes are thought of that will elucidate important aspects of Standard Model or New Physics. BTeV will have these events archived and will be in position to mine the data.*

We also note that the e^+e^- B factories would have total of 10^9 $B\overline{B}$ events in an accumulated data sample of 1000 fb^{-1}, should they reach that level; both LHCb and BTeV will surpass them in 2010, but not before. The B factories, however, do not do B_s physics and there is opportunity there for important discoveries with relative small accumulated luminosities; for example, B_s mixing, should it not be measured at CDF.

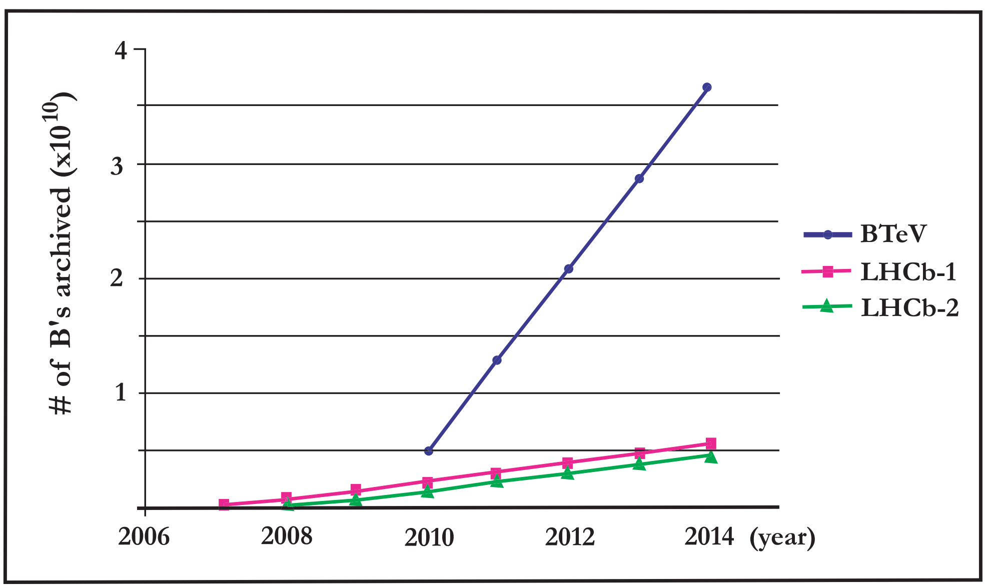

Figure 1.1: The total accumulated number of $b\overline{b}$ events at the end of each year for the staged BTeV detector and the two scenarios for LHCb that are described in the text.

1.4 Specific Comparisons

We now compare BTeV Stage I and II with "LHCb Light" on specific final states. We use four modes of great importance because they give direct determinations of the CP violating angles γ, α and χ, and one rare decay mode.

1.4.1 A Specific Comparison: $B_s \to D_s^{\pm} K^{\mp}$

A time dependent flavor tagged asymmetry measurement in this mode measures the CP violation angle γ. The branching ratio is estimated as $\mathcal{B} = 3 \times 10^{-4}$.

A comparison of the estimated total efficiencies (excluding D_s decay branching ratios), and signal/background (S/B) ratios are given in Table 1.1. Here $D_s^+ \to K^+K^-\pi^+$ can be reconstructed via either $\phi\pi^+$ or $K^{*o}K^+$. BTeV analyzes them somewhat differently. For $K^{*o}K^+$ BTeV requires both charged kaons to be identified by the RICH detector, while for $\phi\pi^+$ only one charged kaon is required to be identified in the RICH. We have derated the BTeV event numbers by 10% to account for effects due to the 396 ns bunch spacing (see the appendix to the TDR [1]). (The reconstruction efficiency for $\phi\pi^+$ is 2.3%, while for $K^{*o}K^+$ it is 1.3%). (All LHCb numbers are taken directly from the LHCb Light TDR [11].)

Table 1.1: Comparison of BTeV Stage I and LHCb sensitivities for $B_s \to D_s^{\pm} K^{\mp}$

	BTeV Stage I	BTeV Stage II	LHCb[11]
Yield (2 fb^{-1})	6,750	6,750	7,140
S/B	7	7	>1
$\epsilon \cdot D^2$	9.8%	13%	7.1%
Tagged yield (2 fb^{-1})	660	878	507
Error in γ for 2 fb^{-1}	9.4°	8.4°	14.5°
Error in γ/year (steady state)		10.9°	26.5°

We note that even without the liquid radiator the effective tagging efficiency for BTeV ($\epsilon \cdot D^2$) is higher than LHCb, this being due to the much lower charged multiplicities in the primary collision. In Fig. 1.2 we compare the error on γ as a function of time for BTeV and LHCb using the two scenarios for the LHC turn on. We note that at the end of 2010 BTeV will have the best measurement of γ using this method and at the end of 2012 the error will be less than 6°.

It becomes pertinent to ascertain when the angular uncertainty falls into a range where there really is a meaningful measurement. We turn to current data for guidance. Both Babar and Belle have measurements on the CP asymmetry in the process $B^o \to \phi K_s$. The measurements of the asymmetry give $\sin 2\beta$ values of $0.47 \pm 0.34 \pm 0.07$ for Babar and $-0.96 \pm 0.50 \pm 0.10$ for Belle [15]. The Babar measurement has $\sim \pm 12°$ error, and the Belle

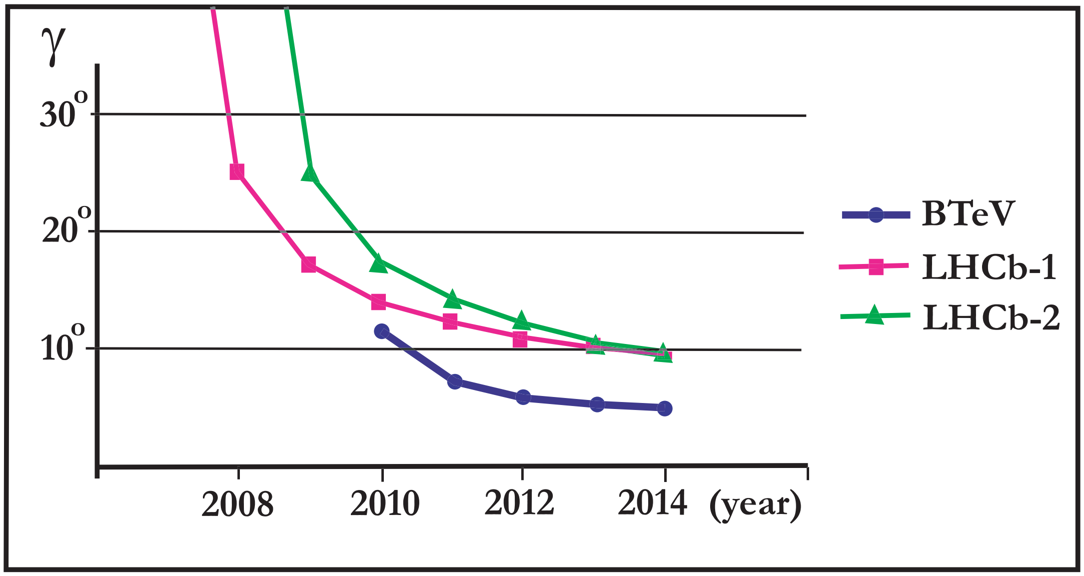

Figure 1.2: The error in the CP violating angle γ (in degrees) as a function of the end of the year, measured using flavor tagged $B_s \to D_s K^-$ decays for the staged BTeV detector and the two scenarios for LHCb that are described in the text.

error is asymmetric and much larger positive error $\sim +22^\circ$, than negative $\sim -8^\circ$, since $\sin 2\beta$ cannot be smaller than -1. These measurements are clearly are not good enough to establish a difference with the value of $\sin 2\beta$ from $B^o \to J/\psi K_s$ decays of 0.74±0.05, which has an error of 2°. This example leads to claim that an error substantially better than 10° on γ will need to obtained before a definitive determination can be made.

Thus LHCb will not likely have a meaningful measurement of γ in either of their turn on scenarios before BTeV, nor will they ever make a measurement as good as BTeV's.

1.4.2 A Specific Comparison: $B^o \to \rho\pi$

This mode has been extensively analyzed by BTeV [1]. LHCb has analyzed this mode somewhat and listed the results in their new TDR [11]. Their detector is not particular well suited for π^o's. In the $B \to \pi^+\pi^-\pi^o$ mode they find that 2/3 of the π^o's form two clusters with a mass resolution of 10 MeV, the other 1/3 are merged. In BTeV the π^o mass resolution 3.1 MeV and only about 10% of the π^o's are merged, but can easily be measured with good resolution using the individual crystal energies. The resultant B mass resolutions are 28 MeV for BTeV and 75 MeV for LHCb.

LHCb estimates a signal yield of 7260 events in 2 fb^{-1}(using our values for the branching ratio). However they only quote a limit of <7.1 on the background over signal ratio based on a sample of 5 background events. They do not quote a sensitivity to α. BTeV estimates a sensitivity in α of 6.3° for the Stage I detector in 2 fb^{-1}, and 4.2° for Stage II. We can make a estimate of the LHCb sensitivity based on the number of events they will detect and their signal to background ratio, if we assume that their decay time resolution is same as BTeV's and their backgrounds in the Dalitz plot are similar in shape. This exercise yields an error in α for LHCb of 11.7° in 2 fb^{-1}. *Since LHCb will accumulate only half the integrated luminosity of BTeV per year, it is clear that they will not be able to make a definitive measurement of* α*, in fact, it is likely that they will not be able to make one at all, not surprising because of the poor energy resolution and segmentation of their calorimeter.* Therefore, it is clear that our results even in Stage I will dominate theirs.

1.4.3 A Specific Comparison: Measurement of χ

The phase of B_d mixing is given by the CP violating angle β. In B_s mixing the phase is called χ and is a fundamental measurement. LHCb because of their relatively poor Electromagnetic Calorimeter LHCb must rely on the vector-vector final state in the reaction $B_s \to J/\psi\phi$. Here the sensitivity is related to several questions beyond the event yields and signal to background. The final state particles are in both CP + and CP - final states and the sensitivity is a sharp function of this ratio. The sensitivity also depends on knowing $\Delta\Gamma$, the difference in widths between the two CP states. LHCb claims that with precise knowledge of $\Delta\Gamma$ and a favorable ratio of CP eigenstates, namely that one is dominant, that they will be able to measure χ to about 3.6° in 2 fb^{-1}. Using the CP eigenstates $B_s \to J/\psi\eta^{(\prime)}$ alone, BTeV's error is 0.7° and BTeV can add in the $J/\psi\phi$ mode if it is at all useful. Since BTeV is expected to accumulate two times as much luminosity per year, we will dominate this measurement even in Stage I. Moreover, BTeV can use its lifetime measurements in $J/\psi\eta^{(\prime)}$, a CP + final state combined with the lifetime in the mixed $D_s^+\pi^-$ final state to get a measurement of $\Delta\Gamma$, and thus provide useful information for the analysis of CP violation in the $J/\psi\phi$, which can lead to the removal of ambiguities in χ and ambiguities in γ using other final states.

The projection of the sensitivities in χ are summarized in Table 1.2. The Standard Model expectation for χ is 1-1.5°. Thus measuring χ to better than 1°, is important, because there are important Standard Model test associated with a precision measurement of χ [2]. New physics, however, can produce significantly larger values, and thus any new measurement could lead to an important result. Although we have listed here the BTeV error using CP eigenstates, BTeV will also measure the $B_s \to J/\psi\phi$ mode as LHCb does, thus somewhat improving the sensitivity.

CDF and D0 also can use the $B_s \to J/\psi\phi$ mode to measure χ. Currently both are reconstructing about 1 event per pb^{-1}. This implies that if B_s oscillations are also measured that they each can measure χ to about 13° [16]. In Fig. 1.3 we compare the error on χ as a function of time for BTeV and LHCb using the two scenarios for the LHC turn on. LHCb will have a chance in 2009 of making a significant measurement of χ, if it is in excess of $\sim 20°$ and they collect sufficient integrated luminosity to improve over the combined CDF and DO measurement. At the end of 2010 BTeV will have the best measurement of χ and the error will eventually be less than 0.5°. *Thus BTeV has the best chance of making a significant*

Table 1.2: Comparison of BTeV Stage I and LHCb sensitivities for measuring χ in 2 fb^{-1}, where BTeV uses $B_s \to J/\psi\eta^{(\prime)}$ and LHCb $B_s \to J/\psi\phi$

	BTeV Stage I	BTeV Stage II	LHCb[11]
Yield (2 fb^{-1})	6,800	11,340	100,000
S/B	20	20	>3
$\epsilon \cdot D^2$	9.8%	13%	5.5%
Tagged yield (2 fb^{-1})	660	1474	5500
Error in χ for 2 fb^{-1}	1.1°	0.7°	3.7°
Error in χ/year (steady state)		0.9°	5.9°

measurement if new physics is present and is the only detector that can measure χ if new physics doesn't make a very large contribution.

1.4.4 Measurement of the Rare Decay $B^o \to K^{*o}\mu^+\mu^-$

This decay mode is one of the most interesting rare decay modes used for finding new physics by examining the polarizations. Normalizing to a branching ratio of 1.5×10^{-6} the rates for BTeV and LHCb are listed in Table 1.3. This is one of the best modes for LHCb. They have a special dimuon trigger that enhances their rates in this final state. Here there is no difference between the rates in BTeV Stage I and Stage II. We also list in the Table a "polarization asymmetry quality factor," that is proportional to

$$QF = \sqrt{1000/(\#\text{ of events})} \times \sqrt{(\mathrm{S}+\mathrm{B})/\mathrm{S}}\ , \tag{1.1}$$

so that smaller QF are better.

Table 1.3: Comparison of BTeV and LHCb sensitivities for $B^o \to K^{*o}\mu^+\mu^-$

	BTeV	LHCb[11]
Yield (2 fb^{-1})	2277	5546
S/B	7	>0.5
QF	0.71	0.74
Yield in 1 calendar year	1700	1660
QF/year steady state	0.63	1.34

In Fig. 1.3 we show the QF versus year. Here LHCb is more competitive than in the other cases. BTeV still dominates at the end of 2010 or 2011.

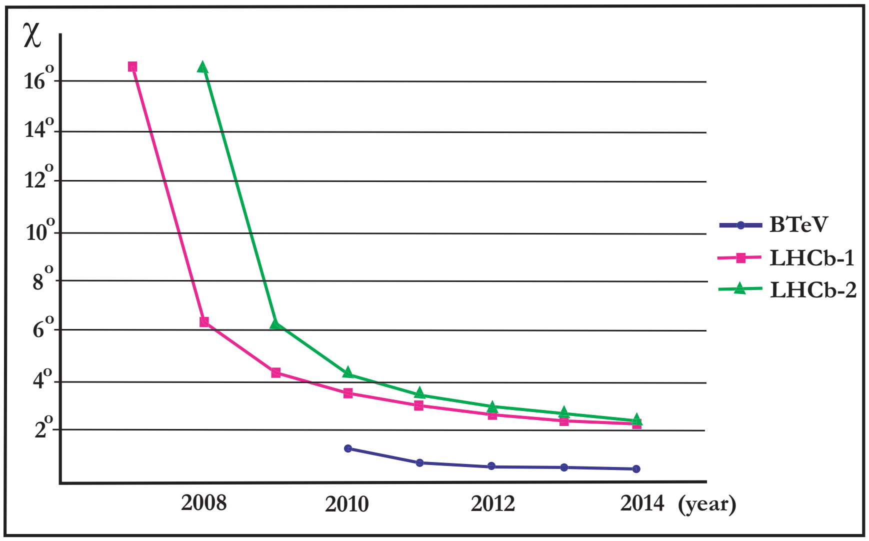

Figure 1.3: The error in the CP violating angle χ (in degrees) as a function of the end of the year, measured using flavor tagged $B_s \to J/\psi\eta^{(\prime)}$ decays for the staged BTeV detector and the two turn on scenarios for LHCb that are described in the text using the $B_s \to J/\psi\phi$ decay mode.

1.5 Summary of Comparisons

BTeV has all the proper elements to make it the "best of breed" heavy quark experiment. It has a relatively unbiased vertex trigger that allows it to accumulate b and c quark events at unprecedented rates. Like the B-factories it has both excellent charged particle identification and photon detection. Furthermore it is coupled to a prolific source of b quarks that permits the experiment to collect 1 kHz of b decays. Some examples of BTeV's prowess have been discussed: BTeV will make the best measurements in the world on the important CKM angles α using $B^o \to \rho\pi$, γ using $B_s \to D_s^{\pm}K^{\mp}$ and χ using $B_s \to J/\psi\eta^{(\prime)}$ even with the Stage I detector. Furthermore, BTeV will write to tape a factor of 10 more b events per calendar year than LHCb, allowing for more physics studies. This is of particular importance because there are many new ideas in this field where new decay modes are "discovered" to be of particular value. BTeV will have these on "tape."

The comparisons done here with assume two LHC turn on schedules for LHC startup. We have no way of knowing how long it will take for the LHC itself to run at high luminosity and how the interactions with the other detectors, Atlas, CMS and Alice will effect LHCb's ability to have accesses to work on their detector and how many shutdowns the other experiments and the machine will require. BTeV will be the only experiment running at the Tevatron so it will not face these problems.

BTeV is the best detector to discover New Physics or provide crucial information nec-

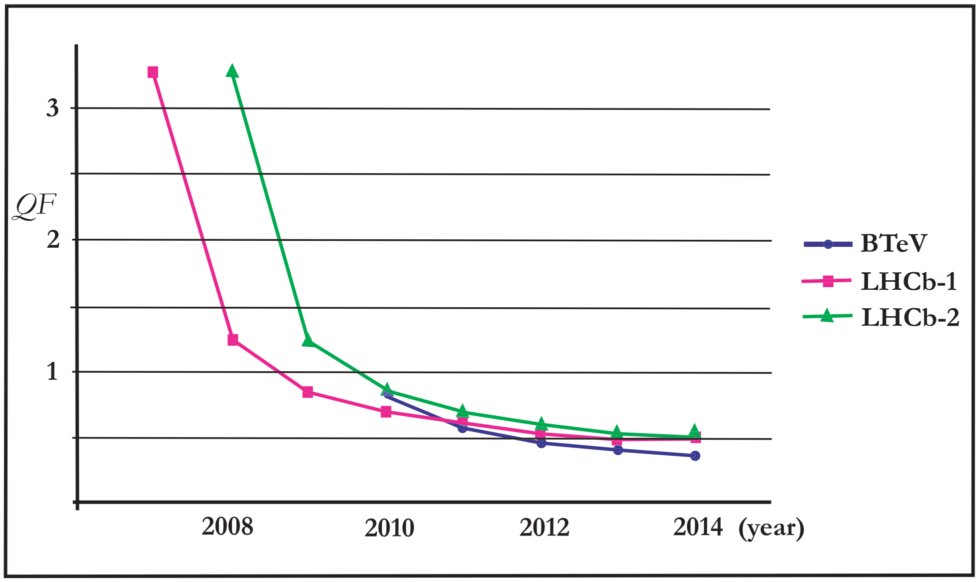

Figure 1.4: The quality factor QF defined in the text as applied to the decay mode $B^o \rightarrow K^{*o}\mu^+\mu^-$, for the staged BTeV detector and the two turn on scenarios for LHCb as a function of the end of year indicated

essary for deciphering any New Physics found at the LHC. LHCb simply cannot do all the necessary physics.

Bibliography

[1] http://www-btev.fnal.gov/DocDB/0021/002115/011/index.shtml

[2] http://www-btev.fnal.gov/cgi-bin/DocDB/ShowDocument?docid=3086&version=1 ; the sensitivities have been updated for 396 ns bunch spacing.

[3] "LHCb Technical Proposal," CERN/LHCC 98-4, LHCC/P4 (1998), available at http://lhcb.cern.ch .

[4] BTeV will have a beam crossing interval that at 396 ns bunch spacing is 15.8 times longer. In fact, LHCb's plan is to trigger in their first trigger level on muons, electrons or hadrons of moderate p_t, and detect detached vertices in the next trigger level. For two-body decays, they now believe only the p_t trigger is sufficient.

[5] LHCb has recently recognized this flaw in their design. They have removed the shielding plate on their magnet and now have a magnetic field between 50 and 260 Gauss on their vertex detector. Unfortunately this also puts 250-1000 Gauss on their first RICH detector, which causes the tracks to bend while traversing the gas radiator and we believe will significantly deteriorate the resolution. It also makes it very difficult to shield the HPD photon-detectors see "LHCb Addentum to the LHCb RICH TDR, *Photon Detectors for the LHCb RICH*," CERN/LHCC 2003-59.

[6] The BTeV electromagnetic calorimeter is superior in energy resolution and segmentation to LHCb's. LHCb has a Shaslik-style Pb-scintillating fiber device, following a preshower detector. The LHCb energy resolution is $10\%/\sqrt{E} \oplus 1.5\%$, which compares poorly with BTeV's $1.7\%/\sqrt{E} \oplus 0.55\%$. The LHCb detector segmentation is 4 cm × 4 cm up to ∼90 mr, 8 cm × 8 cm to ∼160 mr and 16 cm × 16 cm at larger angles. (The distance to the interaction point is 12.4 m.) Thus the segmentation is comparable to BTeV only in the inner region. (BTeV has 2.8 cm × 2.8 cm crystals 7.4 m from the center of the interaction region.)

[7] P. Collier, "Running in the LHC, Part I Summary of Session 7," presented at LHC Project Workshop - Chamonix XIII (2003); can be found at http://www-btev.fnal.gov/cgi-bin/DocDB/ShowDocument?docid=3062&version=1 .

[8] Projections of integrated Tevatron luminosity in the BTeV era as presented by M. Witherell to the BTeV CD-1 Review; can be found at http://www-btev.fnal.gov/DocDB/0030/003018/001/BTeV

[9] P. Ball *et al.*, "B decays at the LHC," CERN-TH/2000-101 [hep-ph-0003238].

[10] The actual amount of commissioning time for the detectors is a complicated issue. BTeV has the advantage of being able to run some parts of the detector using a wire target before the 2009 installation. Plans exist for a test of the magnet, 10% of the pixel system, some straw planes for tracking, the prototype L1 trigger and one DAQ highway. LHCb, on the other hand, will have access to their detector limited by machine tuning, and the desire of the larger ATLAS and CMS groups to keep running.

[11] LHCb Technical Design Report, Reoptimized Detector Design and Performance, CERN/LHCC 2003-030, LHCb TDR 9 (2003).

[12] See T. Nakada, "LHCb Light status and related issue," at http://lhcb-doc.web.cern.ch/lhcb-doc/progress/progress.htm .

[13] The calculation uses $2.8\times10^{32}\text{cm}^{-2}\text{s}^{-1}$ for 139 days with a machine efficiency that includes the fall off of the luminosity with time, filling etc. of 24%.

[14] R. Bailey, "Machine Commissioning: 1st Collisions to 10^{33}," in proceedings of Chamonix XII, CERN-AB-2003-008 ADM, March 2003; J. Virdee, "Requirements from the Experiments in Year 1," ibid. Both can be found at http://ab-div.web.cern.ch/ab-div/Conferences/Chamonix/chamx2003/contents.html .

[15] B. Aubert *et al.* (Babar) [hep-ex/0308035]; K. Abe *et al.* (Belle) [hep-ex/0403026];

[16] The CDF and D0 signals in the $J/\psi\phi$ mode were shown by P. Makismovic, "CP Violation Prospects at the Tevatron," presented at Beauty 2003, see http://www-hep.phys.cmu.edu/beauty2003/ ; the sensitivity to χ is estimated by taking the total Run II integrated luminosity between 4.4 and 8.6 fb^{-1}, a flavor tagging efficiency between 5-10% and a time resolution and signal to background the same as the LHCb projection.